MODEL OF QUALITY MANAGEMENT IN DEVELOPMENT AND MACHINING OF NEW FREE-CUTTING Al-ALLOYS

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SUMMARY
An attempt is made to apply the general model of quality management in the field of development and machining of new ecologically acceptable aluminium alloys for free cutting. Meeting the requirements of ISO 9000 and ISO 14000, the model ensures the fulfilment of the basic requirements leading to the required quality. The incoming material in the form of semi-products (rods) has to be suitably inspected while the parameters of machining have to be selected from the INFOS technological data bank. This statistically supported database ensures a minimum scatter of results which are inspected on the end product. The model will be in this way ensure zero-reject machining.

Key words: Quality management, Ecology, Al-alloys for free cutting

1. INTRODUCTION

One of the pre-requisites for successful production is the use of quality materials with defined mechanical and technological properties. Therefore, for the development and introduction of new kind of material, it is necessary to carry out a number of studies with the purpose to optimise the material composition, fabrication and pre-fabrication procedures, and the resulting material machinability.
Aluminium free-cutting alloys contain lead and bismuth for formation of softer phases in matrix. These phases improve the machinability of alloys giving smooth surface, lower cutting forces are needed, tool wear is lower, and mainly, chips are more easily broken. Since lead is poisonous, a tendency is to replace it with other elements (tin, cadmium, indium) among witch tin is the most suitable. Alloys with tin must have similar or better properties in regard to microstructure, workability, mechanical properties, corrosion resistance, and machinability in comparison with standard alloys. Semi-finished products made from these alloys in the form of bars are used for free cutting or more precisely turning /1,2/.
The aim of this paper is to establish the general model of quality management in the field of pre-forming and machining of semi-manufactures made from new ecologically acceptable free-cutting aluminium alloys. The rationality and economy of manufacturing which are a result of materials saving, energy saving and shorter machining times, depend to a large extend on the right choice of manufacturing procedures, their number and sequence. One of the possible and interesting ways to achieve these aims is by all means the combination of pre-forming, heat treatment and machining /3/.

2. QUALITY MANAGEMENT IN MANUFACTURING

The quality policy. The quality of a company›s product directly affects its competitive position, profitability and credibility in the market. Thus, the major objective of quality management becomes that of achieving and maintaining the leadership in product quality and reliability. Product quality requirements should be defined for each product based on factors related to satisfying the needs and expectations of those whom the product serves and, to the fullest extant possible, be specified in terms enabling objective determination of conformance.

The quality objectives. The overall long-range objectives that the business operation wants to achieve should be defined in such a manner as not only to consider the quality, volume, time and costs associated with market demands, but also to identify the responsibility and authority vested in personnel involved in evaluating and initiating corrective actions in providing solutions to quality problems. The pay-off in this respect should be ideally measured off in terms of financial gains. The typical quality assurance department programme should be prepared to achieve such quality objectives.

The quality system. The concept of overall total quality control system should be encompassed all of the elements of quality assurance and quality control. The main purpose of the quality system is to provide an effective and an economic means of controlling quality and of assuring that manufactured products fulfil their intended purpose with regard to safety, reliability, ecology and performance.
The quality elements, which would be precisely defined are following /4/:

- product quality and reliability development,
- product and process quality planning,
- supplier quality assurance,
- product and process quality evaluations and control,
- special quality studies,
- quality measurement equipment,
- field quality evaluation and control,
- quality information feedback,
- manpower quality.

Stations to be controlled are identified on manufacturing process flowcharts designed for each product. Equipment parameters to be controlled can be determined through operator and set-up man inputs and the plant equipment history and maintenance records review. Process capability studies are valid at this stage to ensure that any variations in the process cycle fall within the acceptable limits established by the engineering specifications.
The right analytical technique is applied to the manufacturing quality problem under investigation such that a correct, and logical, conclusion can be drawn on the appropriate corrective action for product and process improvements. Some problem-solving techniques include the following:

- statistical process control (SPC),
- root cause analysis,
- quality circles,
- quality improvement techniques.

Statistical process control (SPC). Is normally implemented using two basic techniques: either the X-bar and R charts or pre-control techniques (that is machine and process capability studies) /5/. Proper use of statistics to analyse and control processes results in the maximum amount of information from a minimum amount of data. It is therefore the most economical means of controlling a process, and provides faster response time to customer inquiries and quality problems.

Systems analysis methods (SAM). These methods are implemented because they are primarily a language for communication which successfully bridges the divide between management and workers, as well as the divide between workers themselves. SAM allows this effective management and worker communication by identifying and distinguishing between management controllable and worker controllable errors. Normally 80 to 85 per cent of inefficiencies are due to management controllable errors (*the system*), whilst the balance are attributed to worker controllable errors (*within the system*).
The systems analysis methods are based upon the understanding and use of a number of simple statistical methods and techniques, and are applicable to all fields (e.g. engineering, administration, financial, training or production) in all types of industry (e.g. chemical, mechanical or electrical), be it in either the service or manufacturing areas. The model of SAM is shown in diagrammatic form in Fig. 1/6/.
Variation in the elements and sub-elements of the system, and combinations thereof, cause the output to vary over time. This variation is inherent in all systems. As long as the elements vary within natural limits, the variation of the system will be repetitive and predictable. Should any one of the inputs (elements), *e.g.* man, machine, material, method, measuring system or management, vary outside of its natural limits, the system will also tend to vary outside of its natural limits. Management has an extremely responsible role in establishing, maintaining and continually improving the system. The workforce are responsible for working *within* the system.

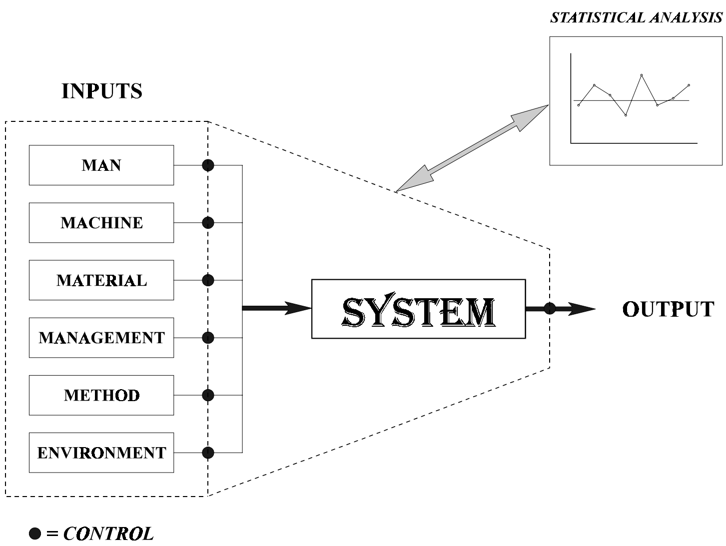

Fig. 1: Systems analysis methods (SAM) [6]

Contemporary manufacturing processes. Since the beginning of this century manufacturing processes have been systematically and scientifically developed and analysed. In the main it has been attempted to achieve, through a high measure of innovation, a maximum efficiency in association with economic manufacturing conditions. The problems associated with environmental protection in relation to manufacturing engineering nowadays take on high priority in industrially advanced countries. The

increasing sensitivity to environmental and health issues is reflected in the increasingly stringent legislation and national and international standards (*e.g.* ISO 14000).
The restrictions resulting from legislation do not only lead to limitations and difficulties with particular manufacturing processes and an associated undesirable cost factor, but also force us to develop new and alternative technologies. This provides a technological challenge to the scientists and engineers and increases the importance of ecological manufacturing as a competitive factor /7/.
High quality of contemporary manufacturing processes depends on three main parameters: *energy, ecology* and *economy.* The model of quality of the contemporary processes is shown in Fig. 2 /8/.

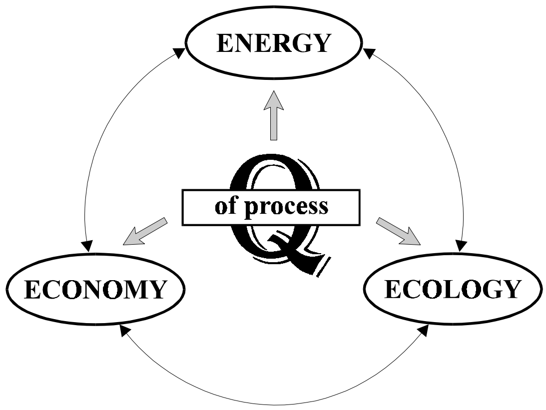

Fig. 2: Quality of contemporary processes - the balance between energy, ecology and economy /8/

The quality objectives that in the phase of technology planning wants to achieve are:

- energy savings,
- ecologically acceptable processes and
- the right choice of manufacturing procedures, their number and sequence.

3. MODEL OF QUALITY MANAGEMENT

The first step of quality management, in the case of pre-forming and machining of semi-manufactures (rods) made from free-cutting aluminium alloys, was carried out by the selection of the type of alloys (Fig. 3).
The most important aluminium free-cutting alloys are Al-Cu with 0.2-0.6 m.% Pb and 0.2-0.6 m.% Bi (AA2011), Al-Cu-Mg with 0.8-1.5 m.% Pb and up to 0.2 m.% Bi (AA2030), and Al-Mg-Si with 0.4-0.7 m.% Pb and 0.4-0.7 m.% Bi (AA6262). In these alloys, mainly lead and bismuth are forming the free-machining phases. In the recent time, a tendency appeared to substitute lead with other elements because it is harmful for human organisms and from environmental reasons [2,9].

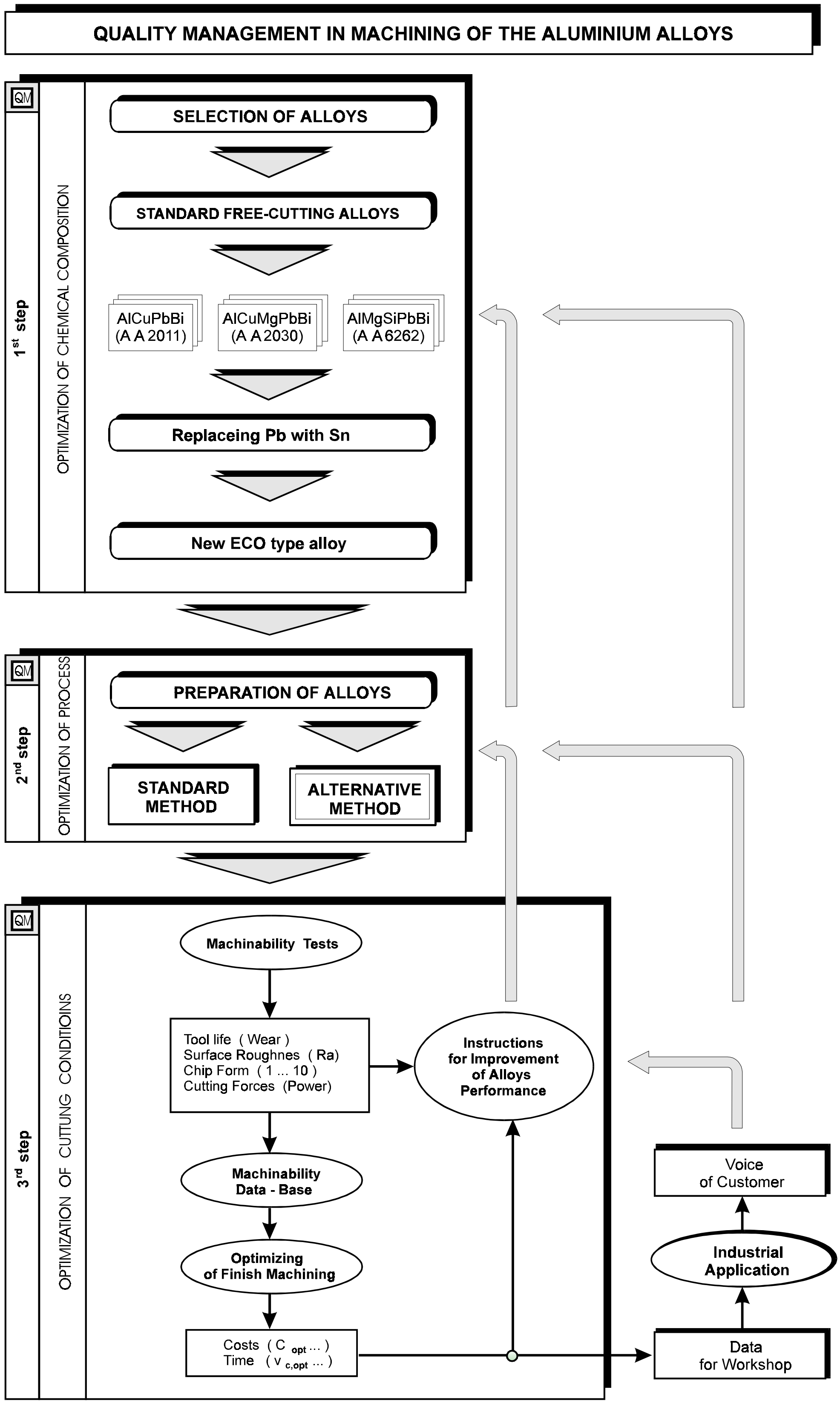

Fig. 3: Model of quality management in the case of machining of the free-cutting aluminium alloys /10/

Tin and partially indium are the most frequently used as substituents. The possibility to apply tin in aluminium free-cutting alloys is known already for a long time /11,12/. Tin was one of the first elements which were added to aluminium free-cutting alloys up to 2 m.%. Its wider use was not accepted into practice due to supposed worsening of corrosion properties, lower ductility of alloys, and high price. In the recent time, tin is added mainly to Al-Mg-Si (AA6000 series) and Al-Cu (AA2000 series) alloys, which normally contained lead and bismuth or only lead /2,3/.

The second step of quality management was carried out by the selection of the method of preparation (pre-forming and heat treating) of semi-manufactures (rods) made from selected type of alloys. In the search for solution and ways to improve manufacturing procedures it is essential that the conventional approach be replaced by new and innovative methods (Fig. 4) which allow us achieve a minimum of environmental contamination in conjunction with suitable technologies providing high process stability and reliability and acceptable economic conditions /8/.

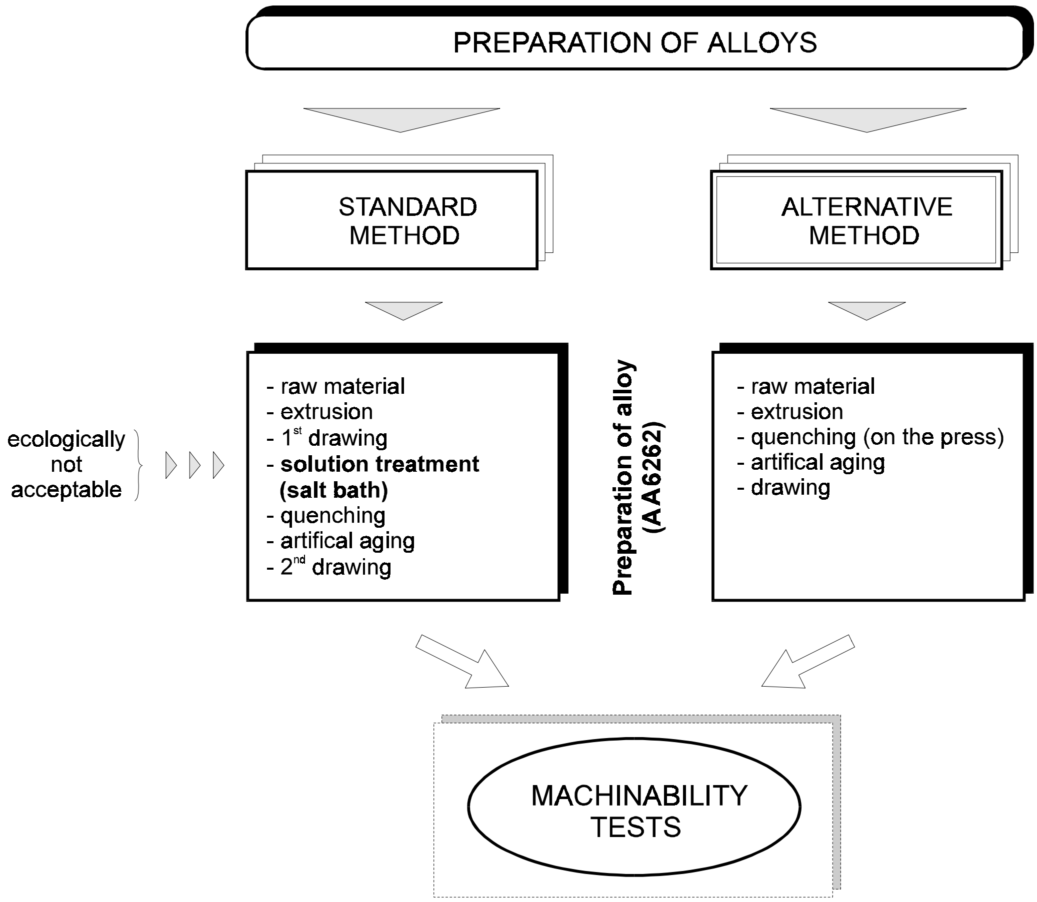

Fig. 4: Different methods of preparation of aluminium free-cutting alloys (2nd step of QM in Fig. 3)

These two methods differ mainly in the manner of solution treatment and quenching. By the *standard method* the extruded and drawn bars were solution treated in a salt bath at a temperature of 525 °C and quenched in water. By the *press quenched method* the quenching took place directly after the extrusion of the material from the die with a water shower. In quenching on the press, solution annealing uses the heat released during extrusion.

The third step of quality management, the decision for the machinability tests offers the correctness of the previous steps on one hand and provides the correct dates about the time and the costs of machining on the other hand, considering the selected parameters of machining and required product quality /13/.
In order to establish the influence of different technological preparation (technological history of worked material) on the machinability by cutting, we need the machinability tests. These tests encompass workpiece materials, cutting tools, and the cutting operation and its characterisation. The considerations used in selecting and evaluating cutting tool performance and workpiece machinability. Besides the machined surface quality chip shape is one of the main criteria for the machinability of free-cutting aluminium alloys.

4. CONCLUSIONS

In many cases present manufacturing processes are not adequately clean. Current trends in the manufacturing world indicate that this situation will not be acceptable in the future and that extensive research and development work is very important in order to meet the future requirements of legislation. The conventional approach has its limitations and that a new and innovative approach is essential within the framework of an environmentally oriented quality management sister. Processes have to be subjected to fine analysis giving detailed consideration to the various inputs and outputs. Combined processes, alternative processes, new technologies, energy requirements etc. have to be evaluated from the environmental perspective.
One good example of the use of alternative processes, in the case of preparation of work material, is the replacement of standard method for pre-forming and heat treatment of aluminium alloys by alternative method (press quenching). The second one is the substitution of lead with tin because it is harmful for human organisms and environmentally not acceptable element.
From the machining process control point of view, one of the pre-requisites is the use of quality incoming material with defined mechanical and technological properties. The purpose of presented model of quality management was to improve the semi-manufactures performance throughout optimisation of chemical composition (1^{st} step) and quality improvement of the technological procedures for pre-forming and heat treatment of aluminium free-cutting alloys (2^{nd} step). In the third phase, according to the requirements of ISO 9000, an attempt was made to apply the general model of quality management also to the field of machining by cutting of these aluminium alloys.
The microstructure and mechanical properties of the alloys, which arise by the different method of pre-fabrication procedures have caused small differences in machinability parameters (tool wear, surface quality, cutting forces). Those values are lower on press-quenched alloys. More than by material properties, these values are affected by cutting parameters. Chip shape plays an important role by machining free-cutting alloys. It is found that chip shape is the most significant parameter of difference when machining alloys, which were prepared by the different method (standard or alternative). The properties of semi-manufactures, analyses of machining tests results and large economic advantages confirm that the *alternative procedure* (press quenching method) can be used for preparation of bars from free-cutting aluminium alloys. Besides better economy in terms of energy consumption, the alternative procedure is also *ecologically more acceptable.*

5. REFERENCES

/1/ Kopač J., Soković M., Smolej A.: Strategy of Machinability of Aluminium Alloys for Free Cutting, *Proceedings of 30th Int. MATADOR Conference*, pp. 156-161, UMIST Manchester, 1993

/2/ Smolej A., Breskvar B., Soković M., Dragojević V., Smolar T.: Properties of lead-free machinable aluminium alloys, *Proceedings of 4th Int. Con. AMPT ´ 98*, Kuala Lumpur, Malaysia, 1998, pp. 145-151

/3/ Smolej A., Soković M., Kopač J., Dragojević V.: Influence of heat treatment on the properties of the free-cutting AlMgSiPb alloy, *Journal of Materials Processing Technology*, 53 (1995), 1-2, pp. 373-380

/4/ Patel B.M.: Manufacturing quality assurance - a systematic and logic approach to effective engineering management, *Quality Assurance*, 1989/2, pp. 56-60

/5/ Weckenmann A., Gebauer U.: Statistical process control in future production, *Journal of Mechanical Engineering*, 44 (1998) 1-2, pp. 4-11

/6/ Lewis E.: Managing with systems analysis methods, *Quality Forum*, 1993/3, pp. 101-105

/7/ Byrne G., Scholta E.: Environmentally clean machining processes - a strategic approach, *Annals of the CIRP*, 42 (1993) 1, pp. 471-476

/8/ Kopač J., Soković M.: Quality management in machining of aluminium alloys, *Proceedings of 12th Int. Con. BIAM ´ 94*, Zagreb, Croatia, pp. G6-G9

/9/ Smolej A., Breskvar B., Soković M., Dragojević V., Smolar T.: Tin in free-cutting aluminium alloys, *Proceedings of 14th Int. Con. AMT ´ 98*, Krynica, Poland, pp. 522-527

/10/ Soković M., Kopač J., Smolej A.: Quality management in machining of free-cutting aluminium alloys, *Metall,* 53 (1999) No. 9, (in printing)

/11/ Zoller H., Enzler G., Fornerod J.C.: Über die Zerspanbarkeit von Aluminium Legierungen, *Aluminium*, 45 (1969), pp. 49-57

/12/ Kutner F., Nachtigal E.: Eigenschaften der Aluminium-Automatenlegierungen, *Aluminium*, 45 (1969), pp. 621-628

/13/ Kopač J., Soković M., Čuš F.: QM and costs optimization in machining of Al-alloys. In: Total quality - Creating Individual and Corporate Success. (Edited by Ahluwalia J.S.), Institute of Directors - Excel Books, New Delhi, 1996